Vacuum/volume 36/numbers 7-9/pages 527 to 529/1986
Printed in Great Britain

0042-207X/86$3.00+.00
Pergamon Journals Ltd

Vacuum system of the multipurpose 14 MeV neutron source in Bratislava: design and status

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The vacuum system of the high flux and low energy deuteron accelerator (10 mA/300 keV) which is under construction at the Institute of Physics in Bratislava, is described. It is designed to give high reliability with little maintenance in order to minimize the radiation hazard in view of the extreme concentration of radioactive tritium.

1. Introduction

The main component of the neutron source[1] is its vacuum system. Basically, it is constructed of stainless steel using ConFlat flanges and copper-gasket seals wherever possible. The pumping itself is to be performed by means of one main and five auxiliary pumping units. The main unit consists of a 2000 ls^{-1} diffusion pump with water and liquid nitrogen (LN_2) traps, two sorption zeolite pumps, a foreline trap and a mechanical pump. Auxiliary units are ion pumps used at both high voltage terminals and each of the three tritium target terminations of the accelerator. This combination has been chosen since its parts are commercially available. All the vacuum system is practically closed in order to minimize the radiation hazard of radioactive tritium desorbed from titanium tritide targets.

The paper gives a rather detailed survey of the design and the present state of the vacuum system of the accelerator.

2. Description of the neutron source

The layout of the source is in Figure 1. The intense section should be capable of producing 300 keV/10 mA of a separated D^+ ion beam. With such a beam and a fresh target a neutron yield of 10^{12} ns^{-1} for a beam spot of 1 cm^2 and a useful target life-time of about 10 h can be expected.

The conventional dc section has been designed to produce a neutron yield of $10^{10} ns^{-1}$ and the fast pulsed section will be capable of generating a compressible D^+ ion beam giving 1 ns^{-1} on a target spot.

The vacuum system of the source has been designed to operate at an average pressure of 10^{-3} Pa. It consists of a 0.108m dia stainless steel beam tube pumped by a combination of ion sorption pumps with a diffusion pump and sorption pumps. All pumping stations are spaced at about 2.3 m intervals and contain, besides pumps, vacuum gauges, electrodes and various beam diagnostic elements. The total length of the accelerator, which contains six pumping stations, is 15 m. Although the pressure requirement is modest, it is designed so as not to use elastomer seals or other organic material. Vacuum chambers will be electrically insulated from the beam tubes to restrict power losses and magnetic field perturbations due to eddy currents.

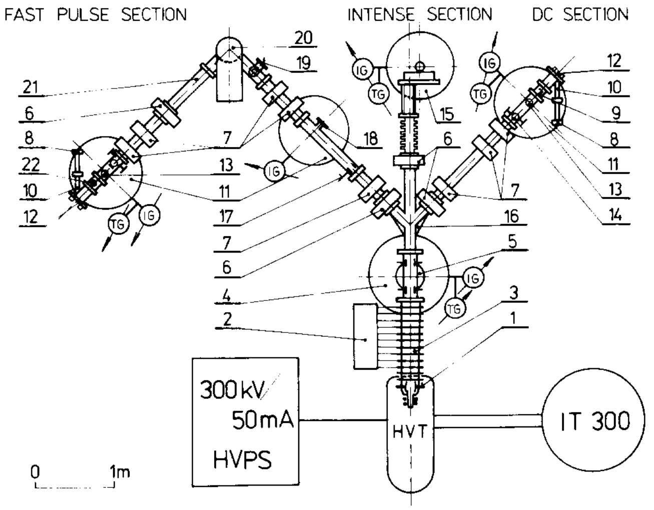

Figure 1. Layout of the neutron source. 1—ion source; 2—column resistor; 3—accelerator tube; 4—main vacuum system; 5—beam steerer; 6—gate valve; 7—quadrupole lens; 8—monitor of α particles; 9—static beam monitor; 10—target chamber; 11—auxiliary vacuum system; 12—water cooled target; 13—water cooled slit; 14—beam profile monitor; 15—rotating target; 16—analysing-switching magnet; 17—chopper; 18—slit; 19—diaphragm; 20–90° magnet; 21—bunching sytem; 22—pick-up system; TG—thermocouple gauge; IG—ionization gauge; IT 300—isolation transformer; HVT—high voltage terminal; HVPS—high voltage power supply.

3. Pumps and gauges

One main and five auxiliary vacuum pumping systems will be used providing clean, safe pumping with pressure monitoring.

3.1. Main vacuum system. For the main vacuum pump, a larger diffusion pump will be used. The scheme of the main pumping unit is shown in Figure 2. A 2000 ls^{-1} diffusion pump together with a

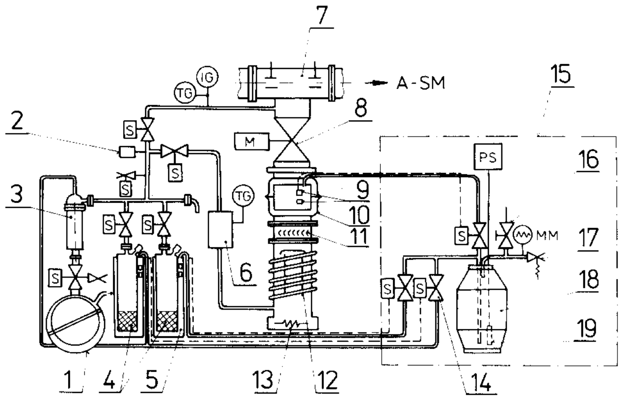

Figure 2. Scheme of the main pumping unit and LN_2 filling device. 1—rotary pump; 2—vacuum relay; 3—foreline trap; 4—sorption pumps; 5—Dewar vessel; 6—vacuum reservoir; 7—beam steerer; 8—plate valve; 9—LN_2 level sensing elements; 10—LN_2 cooled trap; 11—water cooled baffle; 12—diffusion pump; 13—heater; 14—solenoid valve; 15—LN_2 filling device; 16—valve; 17—safety valve; 18—LN_2 reservoir; 19—heater; TG—thermocouple gauge; IG—ionization gauge; A-SM—analysing-switching magnet; M—electric motor; MM—pressure sensor; PS—power supply.

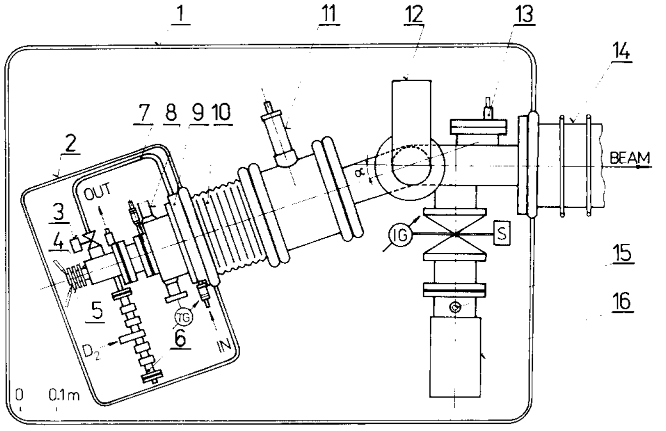

Figure 3. Drawing representing of the high voltage terminal auxiliary vacuum unit. 1—300 kV high voltage terminal dome; 2—50 kV duoplasmatron dome; 3—solenoid valve; 4—cathode feedthrough; 5—cooler; 6—Pd valve; 7—vacuum tube; 8—holder; 9—anode; 10—Al_2O_3 ceramic; 11—50 kV feedthrough; 12—analysing-focusing magnet; 13—D_2^+ beam monitor; 14—accelerator tube; 15—ion pump feedthrough; 16—ion pump.

baffle, and LN_2 trap, two sorption zeolite pumps, a foreline trap and a rotary pump will be used. The calculated pumping speed of the system in the area of the beam steerer is about 250 ls^{-1} for air at 10^{-3} Pa. The reduction of the pumping speed of the diffusion pump is mainly due to the commercially available baffle and LN_2 trap. The calculated pumping speed of the pump in the area of the D_2^+ beam monitor is 60 ls^{-1} for air at 10^{-3} Pa. This pumping speed together with the speed of the auxiliary ion pump suffice to pump also the duoplasmatron during generation of a 10 mA D^+ beam at 10^{-3} Pa.

The diffusion pump usually pumps either with the sorption pump or the rotary pump depending on the pumping efficiency of the molecular sieves used at the LN_2 temperature for hydrogen gases. As soon as a vacuum of 10 Pa is reached, the sorption pump is automatically connected to the diffusion pump while the rotary pump is connected to it when the fore-vacuum increases to 20 Pa.

Two sorption pumps are provided (EGS 500, ref 2). The pumpdown time of the pump operating on 40 l volume from 0.1 MPa to 4 Pa is about 1 h.

3.2. Auxiliary vacuum systems. The auxiliary vacuum systems have been designed to pump the ion source area, the pulse beam line and all target chambers.

A drawing representing the high voltage terminal auxiliary vacuum system is shown in Figure 3. An 80 ls^{-1} triode ion pump (IZ 80, ref 3) will be used. The calculated pumping speed of the pump in the region of the D_2^+ beam monitor is 70 ls^{-1} for air at 10^{-3} Pa. Therefore, the total pumping speed in this place is 130 ls^{-1} for air at 10^{-3} Pa. The calculated total pumping speed is 2–2.5 times larger for deuterium at the same pressure.

A detailed diagram of the auxiliary vacuum unit in the rotating target area is shown in Figure 4. The high vacuum chamber will be pumped by the EGZ 100 ion pump[4] and the rotor of the rotating target is differentially pumped by a rotary pump (1 ls^{-1} at 0.1 MPa) through a foreline trap. The differentially pumped cavity is separated from the high vacuum by three special PTFE 'O'-ring seals fixed by a support. Two Viton rings separate the vacuum cell from the outside environment. The calculated pumping speeds of the ion pump and the main vacuum pump in the area of the target are 85 ls^{-1} for air at 10^{-3} Pa and 65 ls^{-1} for air at 10^{-3} Pa, respectively. Therefore, the total pumping speed in the rotating target area is 150 ls^{-1} for air at 10^{-3} Pa.

The auxiliary vacuum systems of the dc and pulse beam lines are also completed by the EGZ 100 ion pumps (Figure 5). The pumps will be connected to the beam line via an electrically operated valve. The calculated pumping speed of the pumps in the area of the beam is 60 ls^{-1} for air at 10^{-3} Pa.

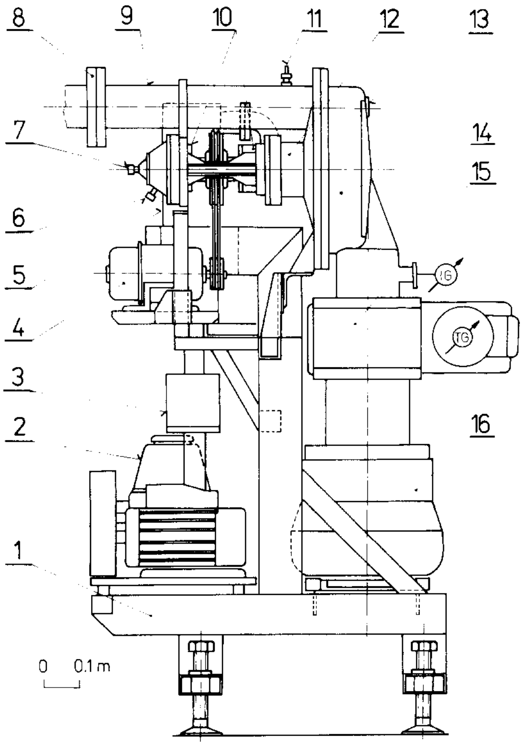

Figure 4. Detailed scheme of the auxiliary vacuum system with the rotating target chamber. 1—holder; 2—rotary pump; 3—solenoid valve; 4—electric motor; 5—foreline trap; 6—water out; 7—water in; 8—flange; 9—beam tube; 10—bearings; 11—feedthrough; 12—stator; 13—sample; 14—rotating target chamber; 15—solenoid valve; TG—thermocouple gauge; IG—ionization gauge; 16—ion pump.

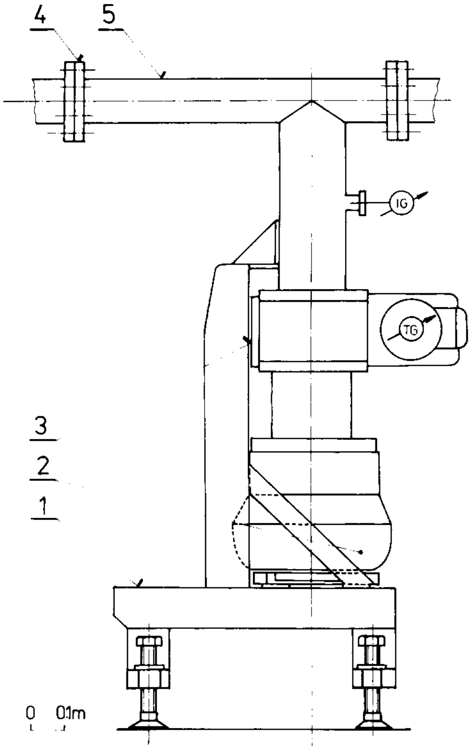

Figure 5. Detailed scheme of the auxiliary vacuum system units in the dc and fast pulse sections. 1—holder; 2—ion pump; 3—solenoid valve; 4—flange; 5—beam tube; TG—thermocouple gauge; IG—ionization gauge.

The pressure inside the system will be measured by thermocouple and Bayard–Alpert ionization gauges. Also, a quadrupole type gas analyser will be installed in the main vacuum system in order to permit quick diagnosis and a residual gas analysis even with the beam on.

A two stage tritium recovery device will be installed in the vacuum system. The first stage is located very close to the target chambers. The recovering principle is based on the pumping of hydrogen gases by the ion sorption pumps and two sorption pumps. The secondary stage is based on the method of oxidation of hydrogen gases with a palladium catalyser doped on aluminium silicate and subsequent absorption of water with a molecular sieve No 5. The whole outlet of the vacuum system is connected to this second stage.

4. Progress to date

The neutron source is now virtually completed. Several components have been developed and successfully tested: (i) the fundamental part of the main vacuum system together with the LN_2 filling device, (ii) the high voltage power supply; (iii) all high voltage transformers, i.e. an isolating transformer 300 kV/10 kVA for the high voltage terminal, the isolating transformer 50 kV/2 kVA for the duoplasmatron and a 50 kV/3.75 kVA transformer for the extraction power supply source.

Under construction are the vacuum electronics, the control system, the high voltage terminal, the diagnostic elements as well as the rotating target.

Acknowledgements

To Ing Š Luby, DrSc the director of the IPEPRC SAS for his support and kind interest in this work. Useful discussions with Dr P Obložinský are also acknowledged.

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